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Math Attitude and Math Anxiety of STEM Students Needs More Attention

Abstract: The issue of math attitude and math anxiety in STEM students has been till now overlooked. However, the issue occurring in many countries is students' falling out of the STEM education system during their studies. One of the reasons for this problem may be high math anxiety and a negative math attitude among students. The present study fills a gap in knowledge about this phenomenon among STEM students. 371 Polish STEM students filled questionnaires of math attitude (MASA) and math anxiety (MAQA, SIMA, AMAS). The results are as follow: The mean results show that STEM students have a very positive math attitude in affective and cognitive dimensions and a rather positive math attitude in the behavioral area; On average, STEM students feel very weak anxiety related to math problem solving, weak general math anxiety and math learning anxiety, and a moderate level of math testing anxiety; Among STEM students there are those who present a very negative/negative math attitude and very strong/strong math anxiety; Women feel more intense anxiety related to math problem solving, but there is no gender gap in general math anxiety, math learning and math testing anxiety, and in math attitude. The results suggest that math attitude and math anxiety of STEM students should be monitored. Indeed, not all STEM students have a positive math attitude and feel no math anxiety. Moreover, proper interventions are recommended to decrease math anxiety and improve positive math attitude that in turn may prevent the students' dropping out from STEM studies.

Keywords: *math attitude, math anxiety, STEM students, STEM education*

INTRODUCTION

Demand for people with high mathematical competence in the labor market is widespread (Caprile, Palmén, Sanz, & Dente, 2015). However, there are many factors that cause the avoidance of science, technology, engineering, and mathematics (STEM) by young people when they choose their field of study (Beilock & Maloney, 2015; Picha, 2018). Moreover, even if students choose to study STEM, 60% of students in the U.S. drop out (Chen, Johri, & Rangwala, 2018). Among risk-factors of dropping out from STEM education are negative math attitude and high levels of math anxiety (Beilock & Maloney, 2015; Picha, 2018; Dowker, Sarkar, & Looi, 2016). While math attitude is defined as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (Neale, 1969, p. 632), math anxiety is understood as "a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of the mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972, p. 551).

Math attitude and math anxiety are closely related to each other, but they are not identical (Catlioglu, Gurbuz, & Birgin, 2014; Ma, 1999). Math attitude is a broader construct than math anxiety because it includes emotions (a liking or disliking of math), beliefs (math is important or not), and behavior (seeking to learn mathematics or avoiding it; Soni & Kumari, 2015; Zan & Di Martino, 2007), whereas math anxiety is concerned solely with emotions (Akin & Kurbanoglu, 2011). Moreover, math attitude is a constant and long-lasting disposition toward math, while math anxiety is a more tentative, intense, and short-lived emotion (Bessant, 1995). Math anxiety is similar to math attitude in that it is considered multi-dimensional. Recent studies have shown that math anxiety is a hierarchical construct and it consists of two general factors: everyday life math anxiety and academic math anxiety. Moreover, academic math anxiety involves math learning and math testing anxiety (Yánez-Marquina & Villardón-Gallego, 2017). Both math attitude and math anxiety are believed to be of great importance to mathematical achievement and math engagement (Zhang, Zhao, & Kong, 2019). It is due to the fact that attitude sets goals for human activity: emotions related to math and

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math beliefs direct engaging in mathematical activity (Ma & Kishor, 1997).

The consequences of negative emotions, beliefs, and the avoidance of mathematics among learners are well-known and have been discussed on the international forums (OECD, 2015). Both a negative math attitude and high levels of math anxiety are significant and negative predictors of mathematical achievement (Hembre, 1990; Ma, 1999; Zhang et al., 2019). It is also known that emotions and beliefs related to math are key factors that affect young people's decisions about choosing STEM as their field of study (Ahmed, 2018; Brewster & Miller, 2020). Most of the studies on math attitude and math anxiety are conducted among elementary pupils (Cargnelutti, Tomasetto, Passolunghi, 2017; Szczygieł, 2019), high school learners (Ma & Xu, 2004; Mann & Walshaw, 2019), and university students majoring in humanities or social sciences (Núñez-Peña, Pellicioni, & Bono, 2013; Zeidner, 1991). Researchers and teachers undertake various interventions to help students suffering from math anxiety and expressing a negative math attitude before they choose college (Beilock & Willingham, 2014; Brunyé et al., 2013). Making effort to help those who have a sufficient cognitive ability to study STEM is reasonable for educational and economic reasons, but their concerns about mathematics limit this choice (Brewster & Miller, 2020; Peters et al., 2017). However, once learners have selected college, their needs are usually no longer attended to by teachers and researchers unless these learners are prospective preschool and early education teachers (Catlioglu et al., 2014; Harper & Daane, 1998; White, Way, Perry, & Southwell, 2005/2006). Intensive research on math attitude and math anxiety is conducted among pre- and in-service preschool and elementary school teachers as well as mathematicians because it was observed that teachers affect the math anxiety, math attitude, and math achievement of their pupils (Beilock, Gunderson, Ramirez, & Levine, 2010; Ramirez, Hooper, Kersting, Ferguson, & Yeager, 2018; Szczygieł, 2020).

However, less is known about the levels of math attitude and math anxiety among STEM students. Research interests mostly focus on gender differences in undertaking studies in STEM area (Delaney & Devereux, 2019) or correlates of STEM outcomes. It is often considered that STEM students have a very positive attitude toward math and do not feel math anxiety. This is because a negative math attitude and high math anxiety are expected characteristics of people with low-level math skills and a factor related to avoiding math activity, while STEM students have high math skills and they have chosen a math-related field of study (Szczygieł, 2021). However, the issue may be more complex since not all of the students who have started STEM studies continue their learning in this area. Therefore, it is important to investigate factors that may cause students to drop out (Chen, et al., 2018; Pinxten, De Laet, Soom, & Langie, 2015; Prieto & Dugar, 2017). These factors may be math attitude and math anxiety (Bessent, 1995; Núñez-Peña et al., 2013; Picha, 2018). There are many premises and they are as follows.

General anxiety, such as the anxiety of being tested, judged, and ridiculed, underlies math anxiety, so it seems reasonable that even people who value mathematics may feel some level of math anxiety in some situations (Whyte & Anthony, 2012). This is particularly relevant to math testing anxiety because anxiety related to evaluation is relatively high in the adult student population (Cipora et al., 2015; Hart & Ganley, 2019). Negative emotions that accompany being tested in math may generalize to negative mood and the formation of unpleasant emotions. However, it seems likely that daily activities related to mathematics should not be very stressful for STEM students; therefore, their math learning anxiety should be very low. The beliefs about mathematics should also be very positive in STEM students. Otherwise, they may be at risk of dropping out of study. The issue of intensity of general math anxiety is more debatable because it may contain a lot of different categories (e.g. anxiety related to evaluation, learning, math teachers, math problem solving, and past and present experiences). Nevertheless, the general level of math anxiety should also be relatively low, especially if the beliefs about math are positive. It is also interesting whether a gender gap in math attitude and the intensity of math anxiety could be observed in STEM students. On the one hand, during their years of education, women systematically reported a higher level of math anxiety than men (Núñez-Peña, Suárez-Pellicioni, & Bono, 2016); on the other, girls who choose a STEM field of study are most likely less math-anxious than non-STEM girls. STEM girls also should have a more positive math attitude than girls who choose e.g. humanities or social sciences (Szczygieł, 2021). Finally, it may be supposed that individual differences occur in the level of various types of math attitude and math anxiety. This means that among adult learners there are those who have positive or negative attitudes to math and feel various levels of math anxiety. It is important to know how many of STEM students manifest an extremely high level of math anxiety, disliking of math, negative beliefs about math, and math avoidance. If there are STEM students with a negative math attitude and high levels of math anxiety, interventions that help them overcome a negative attitude and anxiety may be needed (Brewster & Miller, 2020; Peteres et al., 2017).

Summing up, although the math attitude and math anxiety issue has been explored for many years, little attention is paid to students who study in the STEM fields. Since math attitude and math anxiety are believed to be the factors responsible for dropping out of STEM education, this exploratory study will determine whether both variables are a serious problem in the group of STEM students. Therefore, the objectives of the present study are: (1) to explore the math attitude of STEM students in three areas: affective, cognitive, and behavioral; (2) to determine the intensity of different types of math anxiety: general math anxiety, anxiety related to mathematical problem solving, math learning anxiety, and math testing anxiety; (3) to determine the number of students who display various levels of math attitude (from very positive to very negative) and math anxiety (from no math anxiety to very strong math anxiety); (4) to check gender differences in the levels of math attitude and math anxiety.

METHOD

Participants

The study was conducted among 389 students but 18 observations were removed as the participants did not represent the STEM field of study. Therefore, 371 students (181 women, 190 men) of science, technology, engineering, and mathematics (STEM) at the AGH University of Science and Technology in Krakow (Poland) were included in the current study. The mean age of students was $M = 21.99$ ($SD = 1.96$), and it ranged from 18 to 30 years. Participation in the study was voluntary and the participants were not rewarded.

Materials

The Mathematics Attitude Scale for Adults (MASA, Szczygieł, 2021) is a 19-item scale intended to measure math attitude in three areas: affective (MASA-A), cognitive (MASA-C), and behavioral (MASA-B) on a four point scale (1 – definitely negative math attitude, 4 – definitely positive math attitude). The MASA shows very good psychometric properties in the general adult population. The reliability of the scale in the present study was: for the total score $\alpha = .88$, for the cognitive dimension (6 items) $\alpha = .77$, for the affective dimension (6 items) $\alpha = .81$, and for the behavioral dimension (7 items) $\alpha = .83$. The test retest reliability calculated in the validation study was: $r = .92$ for the total score, $r = .85$ for the cognitive score, $r = .90$ for the affective score, and $r = .86$ for the behavioral score (at six to eight weeks, $N = 71$).

The Math Anxiety Questionnaire for Adults (MAQA, Szczygieł, 2021) is intended to measure math anxiety related to math problem solving. The MAQA is unidimensional scale that includes 19 simple math problems (e.g. calculating the average fuel consumption of a car; calculating the surface area of a sphere). The participants are asked to assess their anxiety toward each of the math problems listed in the questionnaire (1 – definitely do not feel anxious, 4 – definitely feel anxious). The higher the MAQA score, the more intense anxiety related to math problem solving. The scale shows very good psychometric properties in the general adult population. In the present study, the internal consistency of the scale was $\alpha = .92$. The test-retest reliability checked in the validation study and calculated at six to eight weeks was $\alpha = .85$ ($N = 71$).

The Single Item Math Anxiety Scale (SIMA, Ashcraft, 2002; Núñez-Peña, Guilera, & Suárez-Pellicioni, 2014) is intended to measure general math anxiety with one question: "On a scale from 1 to 10, how math anxious are you?" The anchors for the scale were: 1 – not anxious, 10 – very anxious. The higher the score, the higher the level of general math anxiety. The test-retest reliability of the SIMA calculated in a different study involving a Polish sample was $r = .72$, $N = 50$ (at four to six weeks).

The Abbreviated Math Anxiety Scale (AMAS, Hopko, Mahadevan, Bare, & Kunt, 2003; the Polish language version: Cipora, Szczygieł, Willmes, & Nuerk, 2015) is a well-known nine-item scale intended to measure general math anxiety (AMAS), math learning anxiety (AMAS-L), and math testing anxiety (AMAS-T) on a five-point scale (1 – mild anxiety; 5 – strong anxiety). The higher the number of points, the higher the level of math anxiety. The internal consistency of the scale in the present study was: for the total score $\alpha = .88$, for the math learning score $\alpha = .83$, and for the math testing score $\alpha = .90$.

Procedure

The participants attended an online survey. The link to the questionnaire was sent to an AGH employee who sent the questionnaire to all students. The AGH staff member did not have access to the students' responses. Participants were to ensure that the study was anonymous, voluntary, and the results will be used only for research purposes. The aim of the study was presented as a survey on math attitude and math anxiety in adults. Ethical permission was obtained from Ethical Committee at Institute of Psychology, Pedagogical University of Krakow. The students were asked to fill out the questionnaires in the following order: the MASA, MAQA, SIMA, and AMAS, and they were asked about their gender, age, and field of study. Information about their field of study was collected to eliminate from analysis those students who majored in fields other than STEM sciences.

RESULTS

In the first step of analysis, the descriptive statistics were calculated and a series of one-sample t tests was conducted to check whether the mean scores of math attitude and math anxiety differed significantly from criterion (the average score). As the math attitude and math anxiety scales do not have norms, such analyzes let to interpret the results in a more objective way (in relation to the means of achievable results). The effect size was checked using Cohen's d coefficient. The results are presented in Table 1.

The mean score of the scales measuring math attitude among the students (MASA, MASA-A, MASA-C, MASA-B) was moderate or high ($M = 2.79$–3.49). To check whether the results were significantly higher than half of the points available (criterion 2.50), a series of one-sample t tests was conducted. The results confirmed that the math attitude of STEM students was very positive in general, affective, and cognitive areas (a strong effect size) and rather positive in the behavioral dimension (a moderate effect size). To check whether the dimensions of attitude significantly differed from each other, a one-way repeated measures ANOVA was conducted. The results showed that all the mean scores from the MASA-A, MASA-C, and MASA-B were significantly different from each other ($F_{(2,740)} = 290.28$, $p < .001$; Bonferroni post-hoc test, all comparisons $p < .001$). The most positive attitude was observed in the cognitive dimension, then in the affective dimension, and finally in the behavioral area.

Table 1 Descriptive Statistics

Variable	Task	*M*	95% *CI*	*SD*	Min-Max	Skewness	Kurtosis	One sample *t* test	Effect size *d*
Math attitude	MASA	3.15	3.10-3.19	.44	1.58-3.95	-.73	.59	28.56, $p < .001$	1.48
	MASA-A	3.19	3.14-3.25	.53	1.00-4.00	-.84	.90	25.10, $p < .001$	1.30
	MASA-C	3.49	3.45-3.54	.45	1.67-4.00	-1.31	2.36	42.31, $p < .001$	2.20
	MASA-B	2.79	2.72-2.85	.64	1.00-4.00	-.32	-.20	8.70, $p < .001$	.45
Math anxiety	MAQA	1.23	1.20-1.27	.35	1.00-4.00	3.26	15.12	-68.85, $p < .001$	-3.63
	SIMA	2.44	2.23-2.66	2.13	1.00-10.00	1.82	2.58	-27.62, $p < .001$	-1.44
	AMAS	1.79	1.71-1.86	.71	1.00-4.56	1.23	1.53	-19.31, $p < .001$	-1.70
	AMAS-L	1.33	1.27-1.39	.59	1.00-4.60	2.64	7.99	-38.42, $p < .001$	-2.83
	AMAS-T	2.36	2.24-2.47	1.08	1.00-5.00	.56	-.60	-2.57, $p < .01$	-.59

The mean score in math anxiety depended on its dimension. The mean score in the MAQA was 1.23 and was significantly lower than half of the points available (criterion 2.5). The very strong effect size indicated that STEM students felt very weak math anxiety related to solving mathematical problems. The mean score of general math anxiety measured with the SIMA was low and was significantly lower than half of the points available (criterion 5.5). Similarly, the mean score of general math anxiety assessed with the AMAS was low and significantly below criterion (2.5 points). Therefore, general math anxiety in STEM students was weak (a strong effect size). The results of AMAS learning and AMAS testing indicated that the mean scores were below criterion (half of the points available, 2.5). However, the students felt very weak math learning anxiety (a strong effect size) and moderate math testing anxiety (a moderate effect size). The comparison of math learning and math testing anxiety showed significant differences in mean scores ($t_{(370)}$ = -21.53, $p < .001$). The students felt a higher level of math testing anxiety than math learning anxiety.

Because the arithmetic mean represented the average level of math attitude and math anxiety but it failed to indicate how many people showed different attitudes and different levels of math anxiety, questions about the percentage of STEM students who displayed various levels of math attitude and math anxiety were formulated. In Table 2, descriptive statistics are presented showing the percentage of students who had a very negative, negative, moderate, positive, and very positive math attitude as well as the percentage of students who manifested no/very weak, weak, moderate, strong, and very strong math anxiety. The classification was made in accordance with the ranges provided in Table 2.

Table 2 Percentage of STEM Students Who Displayed Various Math Attitudes and Levels of Math Anxiety

Math attitude	Very negative	Negative	Moderate	Positive	Very positive
range	1.00–1.50	1.51–2.00	2.01–3.00	3.01–3.50	3.51–4.00
MASA	0%	2%	31%	46%	21%
MASA-A	0%	4%	35%	36%	25%
MASA-C	0%	1%	17%	30%	52%
MASA-B	4%	10%	53%	21%	12%
Math anxiety	No / very weak*	Weak	Moderate	Strong	Very strong
range	1.00–1.50	1.51–2.00	2.01–3.00	3.01–3.50	3.51–4.00
MAQA	86%	11%	3%	0%	0%
range	1.00–2.50	2.51–4.50	4.51–6.50	6.51–8.50	8.51–10.00
SIMA	69%	17%	5%	7%	2%
range	1.00–1.50	1.51–2.50	2.51–3.50	3.51–4.50	4.51–5.00
AMAS	43%	43%	11%	3%	0%
AMAS-L	79%	15%	5%	1%	0%
AMAS-T	32%	33%	19%	13%	3%

Note: In the MASA and the SIMA, response "1" means not anxious, while in the AMAS "1" means mild anxiety

The analysis of the percentage of students' general math attitude (MASA) showed that almost half of the participants (46%) had a positive and 21% a very positive attitude to math. One-third of the students manifested a moderate attitude (31%), only 2% showed a negative attitude toward math, and none of the students displayed a very negative attitude. The results indicated that the most positive math attitude was shown in the beliefs about mathematics (MASA-C): 82% of the students manifested a positive or very positive attitude toward math. Only 17% of the students had ambivalent and 1% of the students had negative beliefs about mathematics. Definitely fewer students (61%) reported a very positive or positive attitude in the affective dimension (MASA-A), and the learners revealed mixed feelings toward math (35%) twice more often than in the cognitive subscale. Similar to beliefs, none of the students reported a very negative attitude to math, and only 4% reported negative math feelings. In the MASA-B dimension, the students demonstrated an ambivalent attitude most often (53%). One-fifth of the students displayed a positive attitude, only 12% showed a very positive math attitude, and a comparable number of the students (10%) showed a negative attitude in the behavioral area. Only in the behavioral dimension of attitude, there were students who displayed a very negative attitude (4%).

The analysis of the intensity of math anxiety showed that the vast majority of the students did not feel math anxiety or felt very weak/weak anxiety related to mathematical problem solving (97%, MAQA). Only 3% of the students reported a moderate level of anxiety related to solving mathematical tasks, and no one felt strong or very strong anxiety in this area. In the area of general math anxiety (SIMA), the results indicated that some of the students felt very strong (2%), strong (7%), or moderate (5%) levels of anxiety. However, in the MASA, 86% of the students reported no math anxiety or very weak/weak general math anxiety, and 11% of them reported a moderate level of anxiety related to mathematics. The results of the AMAS showed that fewer students reported very weak or weak general math anxiety (68%) and fewer of them reported strong (3%) or very strong (0%) math anxiety. The analysis of the separate results in math learning anxiety and math testing anxiety showed that 94% of the students did not feel anxiety toward learning math, 5% felt moderate and 3% strong math learning anxiety, while 65% of the students manifested very weak or weak math testing anxiety, 19% felt a moderate level, 13% a strong level, and 3% a very strong level of anxiety related to testing situations.

To check whether there were gender differences in the levels of math attitude and math anxiety, a series of independent sample *t* tests was conducted. To estimate the effect size of gender differences, Cohen's *d* coefficient was calculated (see Table 3).

The results showed that women and men differed significantly in anxiety related to math problem solving (MAQA); however, the gender gap in this area was small (d = .31). No differences were observed in math attitude (MASA, MASA-A, MASA-C, MASA-B) and in general math anxiety, math learning anxiety, and math testing anxiety (MAQA, SIMA, AMAS, AMAS-L, AMAS-T).

DISCUSSION

Many countries seek educational policies that would help students who embark on STEM studies to complete them successfully. For this reason, researchers are focused on a variety of factors that play a role in students' departure from STEM fields (Chen, 2014; Pinxten et al., 2015; Prieto & Dugar, 2017). Although some researchers indicate math self-concept and math attitude as significant factors in career choice (Prieto & Dugar, 2017; Tripney et al., 2010), and it is assumed that STEM students interrupt their education because of cognitive and emotional factors (Marra, Rodgers, Shen, & Bogue, 2012; Pinxten et al., 2015), STEM students have been overlooked in studies on math attitude and math anxiety. The

Table 3 Gender Comparison of Math Anxiety and Math Attitude

		Women	Men	Comparison group	Effect size
Variable	**Task**	***M* (*SD*)**	***M* (*SD*)**	***t***	***d***
Math attitude	MASA	3.11 (.47)	3.18 (.40)	-1.36, p = .17	.16
	MASA-A	3.14 (.56)	3.24 (.50)	- 1.83, p = .07	.19
	MASA-C	3.49 (.47)	3.50 (.44)	-.22, p = .83	.02
	MASA-B	2.74 (.67)	2.83 (.60)	-1.40, p = .16	.14
Math anxiety	MAQA	1.29 (.42)	1.18 (.27)	3.16, p = .002*	.31
	SIMA	2.56 (2.32)	2.33 (1.93)	1.05, p = .30	.11
	AMAS	1.83 (.77)	1.75 (.65)	1.03, p = .30	.11
	AMAS-L	1.37 (.65)	1.30 (.52)	1.10, p = .27	.12
	AMAS-T	2.40 (1.16)	2.31 (1.04)	.79, p = .43	.08

Note: Women N = 181, men N = 190; * p < .01

current study fills a knowledge gap about this issue via exploring math attitude, the intensity of math anxiety, and gender differences in these areas.

The results showed that STEM students had a very positive attitude toward mathematics in general; however, some differences appeared in the dimensions of attitude. A very positive math attitude was observed especially in the cognitive area, which confirms that the STEM field of study is a domain of people convinced about the importance, relevance, necessity, and utility of math. The vast majority of the students declared positive or very positive beliefs about mathematics. Although the students manifested a significantly less positive math attitude in the affective dimension than in the cognitive area, their attitude in the affective dimension may still be described as very positive. More than half of the students manifested positive or very positive emotions: they liked and enjoyed math, they felt comfortable about math activity, and they were not anxious because of it. However, their behavior was not very consistent with their beliefs and feelings. The behavioral dimension of math attitude was positive, but significantly less than in other areas. Although the students declared readiness to engage in solving math problems or helping others with math, they did so with moderate conviction. Most students declared a moderate, negative, or very negative attitude toward mathematical activity. The results were consistent with findings on various dimensions of attitudes toward mathematics (Soni & Kumari, 2015; Zan & Di Martino, 2007). Positive beliefs about mathematics do not determine only positive feelings toward math, and they do not always result in a high level of engagement in mathematical activity (Zan & Di Martino, 2007). It cannot be claimed that math attitude in STEM students is negative. It would be surprising and disturbing if STEM students were not convinced of the importance of mathematics. Moreover, it would be alarming if they did not like mathematics and refused to engage in math-related activities. However, the results about their weaker commitment to learning math may result from various factors that were not tested: e.g. too many activities and tests, the level of task difficulty, unsatisfactory teaching methods, pressure on "right methods", fear of bad grades and dropping out (Finlayson, 2014; O'Leary, Fitzpatrick, & Hallett, 2017). Given the level of math testing anxiety in STEM students, this supposition is very likely.

The mean score in math anxiety showed that STEM students generally were not math-anxious. They reported a particularly low level of anxiety related to math problem solving and learning mathematics. Similarly, their general math anxiety may be considered weak. However, the mean score in the testing situation was moderate and significantly higher than math learning anxiety. Over one-third of the students manifested a moderate, strong, or very strong level of math testing anxiety, whereas in other types of math anxiety the vast majority of the students declared no or weak math anxiety. The results were consistent with previous papers indicating that in the adult learner population anxiety related to evaluation was higher than anxiety related to learning (Cipora et al., 2015; Hart & Ganley, 2019). These results are very interesting because they show that although the mean score for math testing anxiety in STEM students is lower than usual in the adult population, it is, however, significantly stronger than the mean score for math learning anxiety. This effect is similar in young and adult learner populations (Cipora et al., 2015). The obtained results may be explained by fear of being tested and evaluated (O'Leary et al., 2017), and they are consistent with a relatively less positive math attitude in the behavioral area. Even if the students value and like math, too many and too hard pop-quizzes and examinations may cause anxiety related to math activity in some situations.

The results showed no gender differences in math attitude, general math anxiety, math learning anxiety, and math testing anxiety, and a small gender gap in math problem-solving anxiety. Although most of the research in elementary pupils, high school learners, and non-STEM students reveals that girls and women have a higher level of math anxiety than boys and men (Núñez-Peña et al., 2016; Schleepen & Van Mier, 2016; Szczygieł, 2019), the obtained results show the contrary but are nonetheless explainable. Goetz, Bieg, Ludtke, Pekrun, & Hall (2013) indicated that the gender gap in math anxiety is revealed if math anxiety is measured as a trait and it disappears if math anxiety is measured as a state. As Goetz et al. (2016) highlighted, females may manifest higher trait math anxiety than males because of the false beliefs about their lower math competence in comparison to males. However, state math anxiety is more pronounced in self-reported gender differences. Because the current study was conducted among students who have regular contact with mathematics, the explanation of Goetz et al. (2013) may also be applied to the obtained results. Women studying STEM may have similar beliefs about their math competence to men because there is no gender gap in math attitudes in the affective, cognitive, and behavioral areas. Moreover, no gender differences in general math anxiety, math learning anxiety, and math testing anxiety may result from similar educational and life goals. Therefore, it can be concluded that the lack of significant gender differences in the level of math anxiety and attitudes toward mathematics is characteristic of people who are involved in daily math-related activities.

On the one hand, the results are optimistic because they confirm what is commonly believed about the attitudes of STEM students toward mathematics and their math anxiety: they value and like mathematics and are not afraid of it. On the other hand, their relatively less positive math attitude in the behavioral dimension in combination with their relatively higher level of math testing anxiety suggests that requirements and tests may result in reduced engagement and less positive feelings related to math. Moreover, although the results indicating the average level of math attitude and math anxiety are calming, the fact that some STEM students feel extremely negative feelings toward mathematics is very alarming. Even if it is a small percentage of people, these data nonetheless reveal that there are students who experience discomfort associated with their field of study. Therefore, it is important to keep a track record of the emotional state of STEM students and, if necessary, apply appropriate interventions the way it is done for other students, e.g. future preschool and early education teachers or mathematicians (Beilock & Willingham, 2014; Brunyé et al., 2013).

The topic of emotions related to mathematics is so important that already in 2008 the United States National Mathematics Advisory Panel formulated recommendations for the development of effective interventions aimed at counteracting the emergence and development of math anxiety (US Department of Education, 2008; Brunyé et al., 2013). Although the aim is clearly stated, the issue of "how to do it" is complex. The lack of unequivocal findings on the direction of the relationship between math anxiety and math performance implicate strategies on reducing math anxiety itself (as a cause of low math achievement) or on supporting the development of mathematical skills (as a cause of math anxiety). For this reason, interventions aimed at reducing math anxiety are closely related to either the recommendations to reduce math anxiety immediately before performing mathematical tasks (Brunyé et al., 2013; Jamieson, Mendes, Blackstock, & Schmader, 2010; Park, Ramirez, & Beilock, 2014; Uusumaki & Kidman, 2004), or to organize educational activities in such a way as to minimize the appearance of negative emotions during math classes (Berkowitz, Schaeffer, Maloney, Peterson, Gregor, Levine & Beilock, 2015; Chavez & Widmer, 1982; Gunderson & Levine, 2011; Núñez-Peña et al., 2013; Juhler, Rech, From & Brogan, 1998; Peters et al., 2017). The results of research in both approaches make it possible to indicate activities that lower math anxiety and improve math skills: exercises for a reinterpretation of physiological arousal, application of expressive writing, training of awareness and systematic desensitization, fighting against stereotypes, use of new technologies, providing feedback, testing and giving another chance to pass the test, teaching methods fitted to the students' abilities and needs. Nevertheless, it should be remembered that these activities must be properly implemented in university conditions and their effects should be monitored. Since math anxiety and a negative attitude toward mathematics are negatively associated with the level of STEM achievement, and low achievement is a determinant of escaping from STEM sciences, it can be assumed that emotions and beliefs may play a significant role in dropping out of studies. However, more studies are needed on this topic. Keep in mind that attitude is not something that can be changed easily or quickly (Albarracin & Shavitt, 2018; McLeod, 1992). Shaping positive math attitudes should start from the early school years and continue through the following years of education (including university).

Future research should also eliminate shortcomings of the study. First of all, the sample was not totally random. The STEM students were recruited only in one Polish academy. Therefore, formulated conclusions are limited to this sample. Moreover, sparse information has been gathered about this group. Therefore, subsequent research should take into account not only math anxiety and math attitude but also previous learning experiences, learning motivation, and STEM outcomes in a larger and more heteronomous random sample. Then, self-report measures in non-random order were used which may have affected the results. Students could present themselves in accordance with the stereotypes of STEM students (positive math attitude and low math anxiety) and girls could have presented themselves as boys-like, believing that it was expected of them. Moreover, math attitude items could affect response in math anxiety questionnaires. In future studies, the order of questionnaires should be randomly selected to eliminate this effect in the whole sample. Students were informed about the objective of the study, so information about the measurement of math attitude and math anxiety could affect participants' enrollment in the study. Students who felt negative emotions towards mathematics and the field of their study could choose not to participate in the study. Thus, the results may be biased by the fact that some people avoid math-related activities altogether, including participation in the math-scientific study. Next of the limitations of the current study is that the students were not asked to provide information about their year of study. Similarly, the responses of those who continued their STEM education in college were not compared with those who had dropped out. Ideally, longitudinal studies would be planned in which high school students would be tested and their educational paths followed, including math anxiety and math attitude. Moreover, it would be interesting to compare the proportion of highly math-anxious and negative math attitude between STEM and non-STEM students. It would show whether a low rate of math anxiety and negative attitude is specific for STEM students. However, it should be remembered that non-STEM groups are varied (e.g. pre-service teachers, in-service teachers, students of humanistic and social science, people who never had been students) and some of them may be more similar to STEM students than others. Therefore, the results of the study should be treated as a preliminary insight into math anxiety and math attitudes among STEM students and as a starting point for further research.

CONCLUSION

The results demonstrated that most of the STEM students had a positive attitude and feelings related to mathematics; however, some of the students had an ambivalent or negative math attitude, and they manifested strong math anxiety. This means that young people who choose to continue their math-related education may experience dissatisfaction and discomfort when their learning environment is far from optimal. Some levels of arousal may be conducive to learning; however, unnecessary and excessive levels of stress, especially those related to testing situations, may result in reduced achievement and mood disorder development. For this reason, it is important that STEM students take appropriate actions to reduce negative emotions that result from studying.

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